Super-FRS magnets: magnetic measurement

Collaboration kick-off meeting

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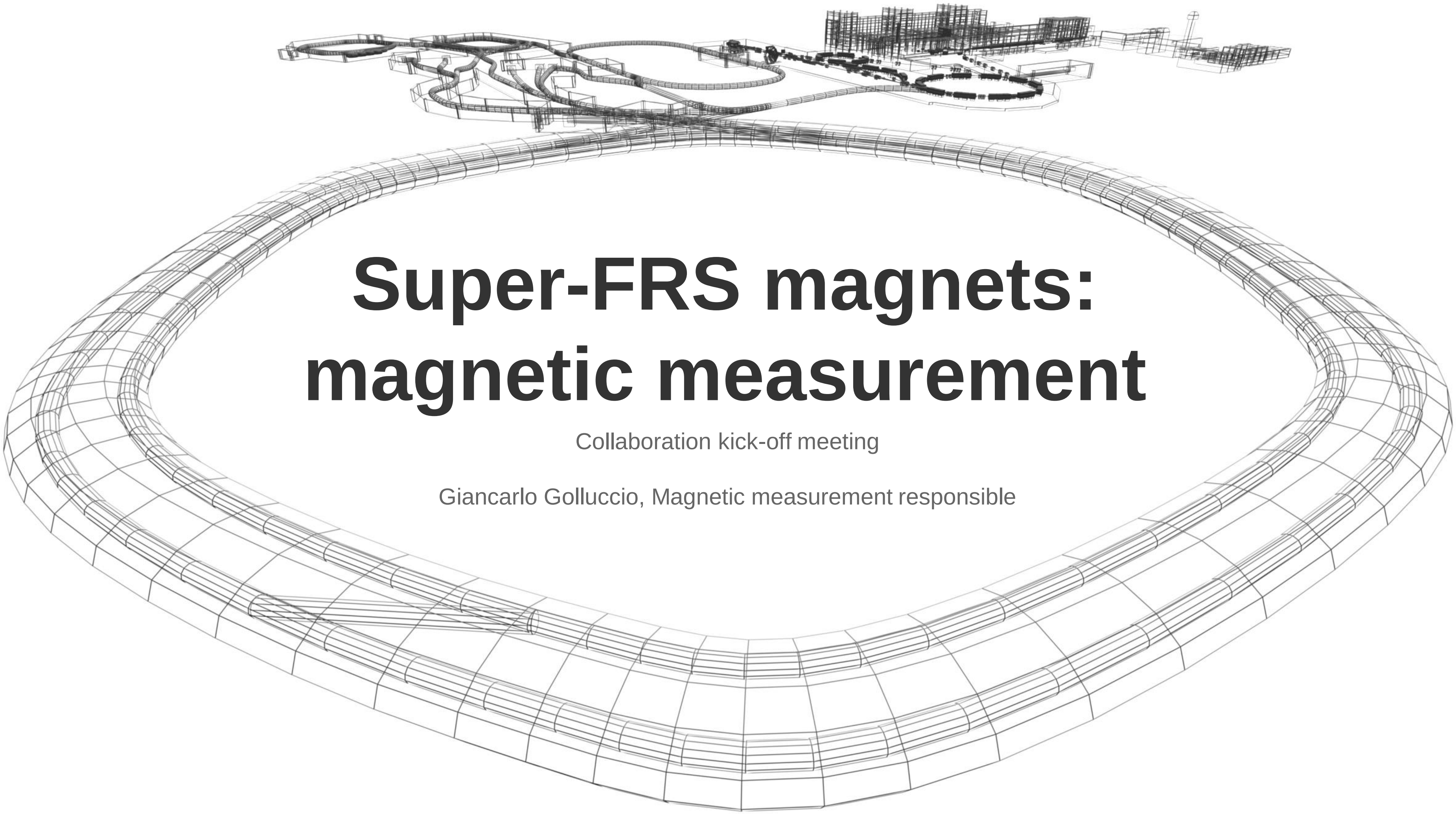


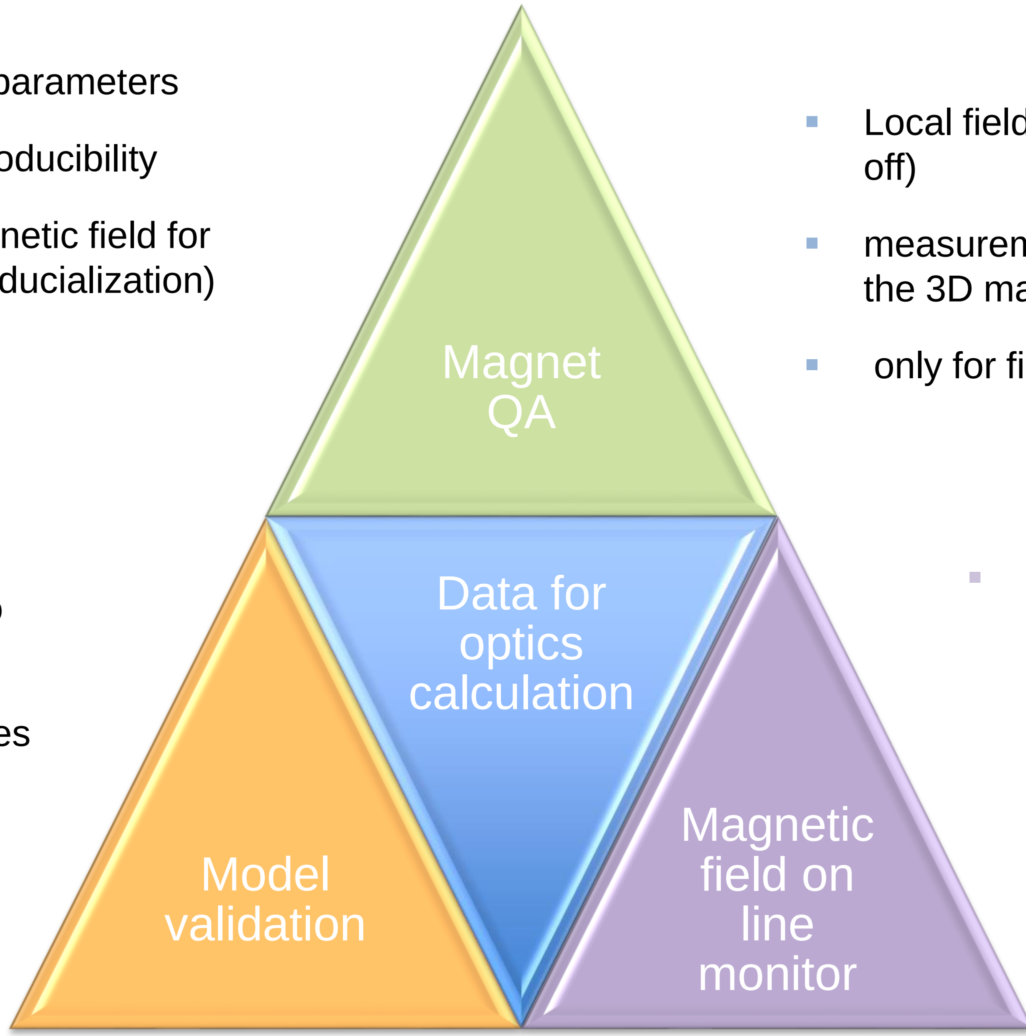
Outline

- **Magnetic measurements campaign**
  - Magnetic measurement requirements
  - Measurement methods
  - Measurement strategy
  - Devices
- **Summary**

Magnetic measurement campaign

- Conformity to QA SAT parameters
- Magnet to magnet reproducibility
- Localization of the magnetic field for installation purposes (fiducialization)

- Local field information (field roll off)
- measurement can be tuned on the 3D magnetic field model
- only for first of series



- Measurement in the 2D region and integral
- Only for the first of series
- Verify mechanical assembly tolerances

- Provide a feedback during operation in control room

Requires: dedicated measurement campaign for sensors calibration

Not planned yet for super-FRS

Magnetic measurement Requirements

- Magnetic measurement for the Super-FRS
  - Requirements from GSI to CERN in the 2014
    - https://edms.cern.ch/document/1416580

Series testing (10 days per multiplet)

Field strength and quality	Main dipoles and Quadrupoles	Current levels	5
		Absolute integral field accuracy	$\pm 5*10^{-4}$
		Integral field homogeneity*	$\pm 5*10^{-5}$
	Multipoles	Absolute integral field accuracy	$\pm 1*10^{-3}$
		Integral field homogeneity	$\pm 2*10^{-4}$
Magnetic axis	Quads and multipoles	Angle (mrad)	<0.5
		Axis (mm) except steerers	0.2

Extended pre-series (40 days per multiplet)

Integral field, integral transfer function, hysteresis and homogeneity at 16 current levels

Full 3D map of the magnetic field at 3 current levels and 3 vertical planes (FoS 11°, FoS 9.75°, 3 branch dipoles)

Local map with 100 mm rotating coil 3 current levels 100 mm step (1 long quad, 1 short quad, 1 sextupole)

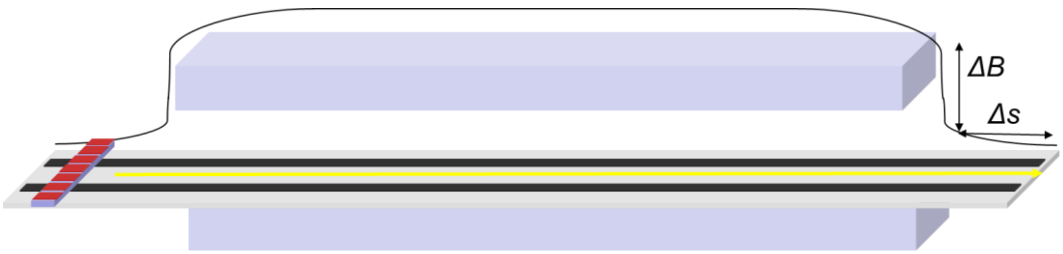
Magnetic measurement Requirements

- Challenges:
  - Large dimension of the Good Field Region
    - 170 mm radius for quadrupoles
    - 380 x 140 mm for dipoles
  - Extended fringe field
    - 4000 mm for dipoles
    - 2600 mm for long quadrupole
  - No possibility of standard calibration procedures
  - Tight requirements of accuracy and fiducialization

Measurement methods

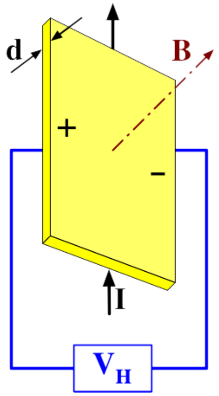
Translating fluxmeter

(voltage induced in a coil during its translating in a field)



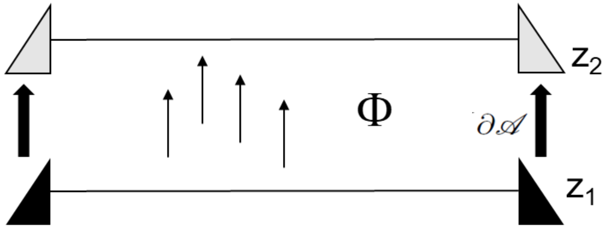
3D Hall sensor

(voltage variation across a conductor crossed by a current immersed in a magnetic field)



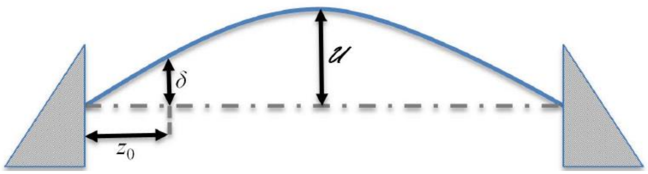
Single stretched wire

(induced flux in a wire displacement)



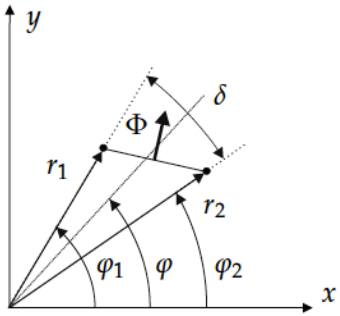
Vibrating wire

(vibration induced in an wire powered with AC current)



Rotating coil

(induced flux in a loop rotating)



Measurement strategy

- **The magnetic field quality is an acceptance criteria for the magnet**

- **Measured for each FOS with two independent systems/methods**
  Dipoles: Translating fluxmeter, Stretched Wire (Vibrating Wire)
  Multipoles: Rotating coils, Stretched Wire (Vibrating Wire)

- **Extended program for FOS**
  30% of the time of the extended program is needed for guaranteeing redundancy and flexibility for the series testing phase:
  Cross-check measurement results
  Results confidence

- **Standard program for the Series**
  - Only integral measurements
  - use of only Stretched Wire measurement is preferable
  - In case of not acceptable divergences w.r.t. FOS measurements, alternative fluxmeter (for dipole) or rotating coil (for multiplet) will be used.
  - The magnetic measurement program at cold for the series is 10 days, however, as function of the results of the first of series this schedule can be adjusted

Measurement strategy

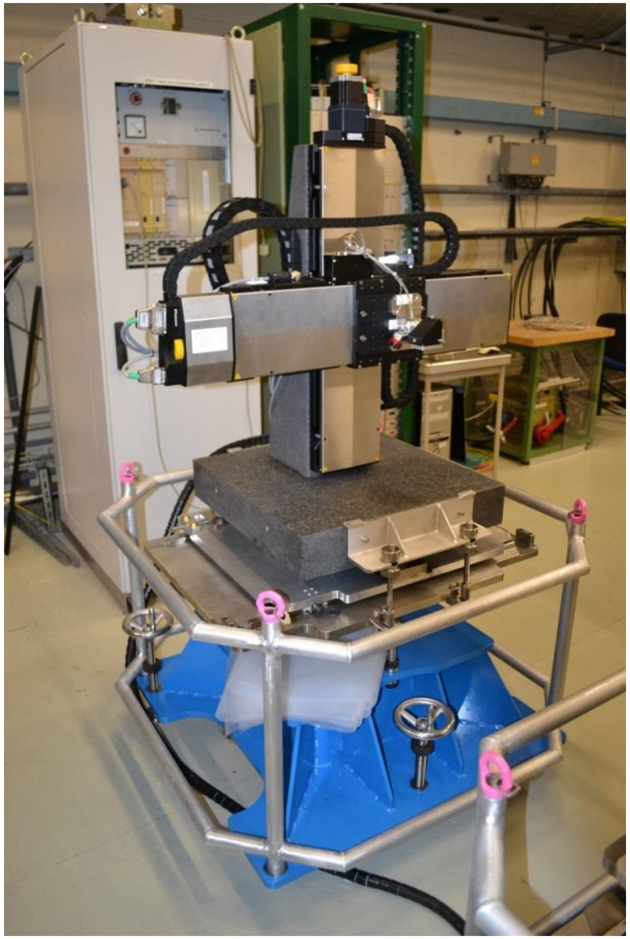
- **Pre-series**
  - enough time for study and cross-checking both global and local field distribution and homogeneity

- **Series**
  - Checking magnet to magnet reproducibility
  - No contingency for tracing manufacturing errors and corrective actions for the magnet is foreseen, for the moment.
  - Under responsible of the magnet work packages, additional measurements might be discussed and can be arranged.

Measurement device status

Stretched wire for multiplets and dipoles

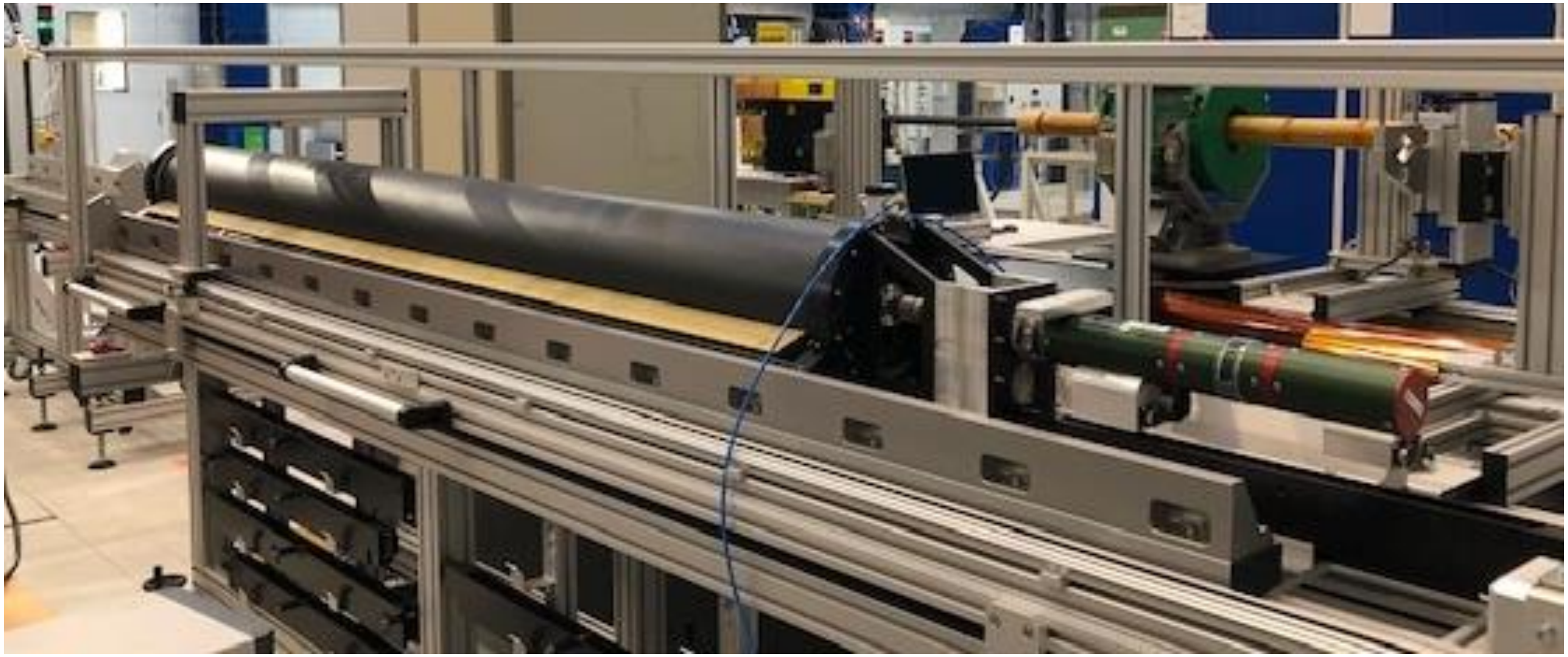
Stages with 400 mm stroke equipped with vibrating wire sensors based on standard CERN design ready for operation



Measurement devices status

Rotating coils for multiplets

2.6 m rotating coil shaft with 350 mm diameter Ready for operation



3 PCBs

- 2 x 1.326 m length
- 1 x 0.1 m length
- 5 Radial coils
- 72 turns 6 layers
- External radius 167 mm

Carbon Fibre structure (2 half-cylinder)

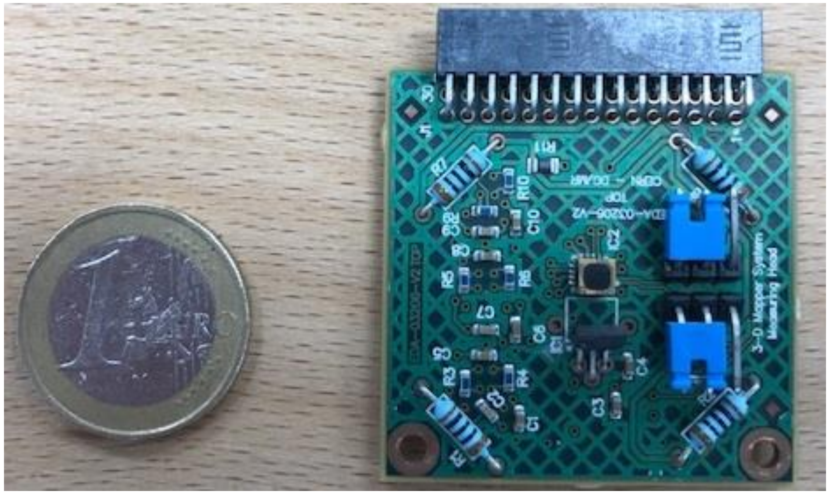
- Support structure for PCB
- rigidity
- Weight reduction

Design principles modular used also for other CERN projects

Measurement devices status

3D mapper for dipole

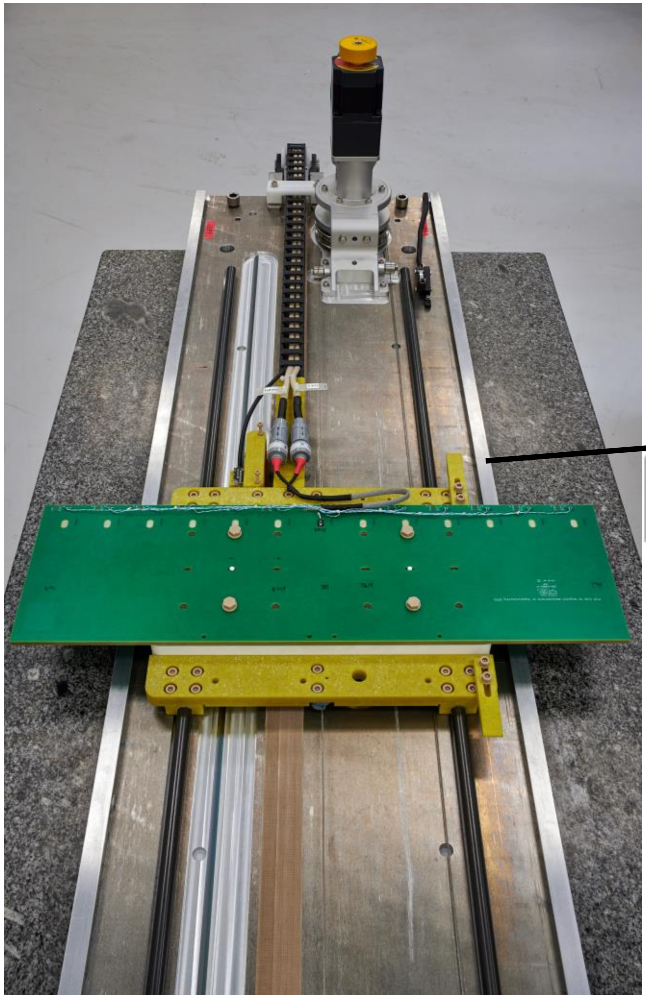
3D stages with 3000 x 1000 x 1000 mm stroke mapper and 3D hall probe sensor



Delivered in May 2019 under commissioning in the 311 facility

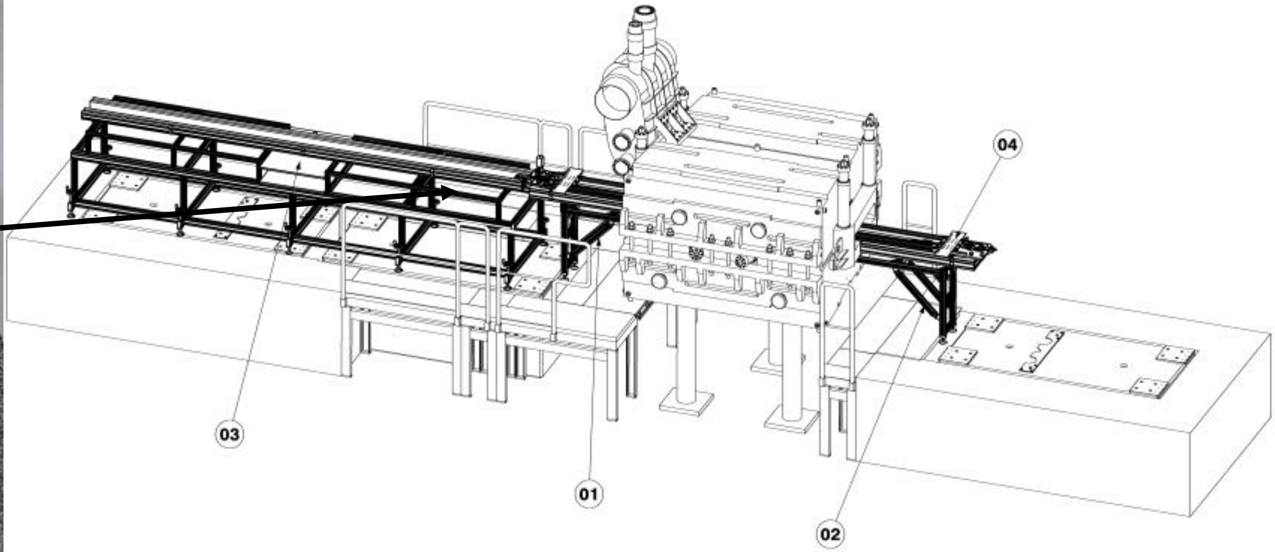
Devices status

4 m measurement length translating fluxmeter for dipoles



PCB plate with
- 13 coils of 0.6 m^2
- 1D Hall probe for offset adjustment

Aluminium structure
- Guiding system
- Non magnetic linear encoder (5 um resolution)



New measurement method for large aperture dipole at the moment under commissioning in 311

Summary

- Magnetic field parameters are relevant for the magnet acceptance
- Extended measurement program necessary to gain results confidence
- Different methods will be used to gain in redundancy and flexibility
- No contingencies for corrective actions during the series test phase
- Measurement devices for the FoS multplet are ready
- Accuracy of results only possible to be estimated in-situ during the FoS testing